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PERFORMANCE INVESTIGATION WITH ASSEMBLY TOLERANCE IN SCROLL COMPRESSORS

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ABSTRACT

The assembly tolerance in scroll-type compressor (STC) is one of the critical factors that influence their performance. This investigation is aimed at three factors including the backlash, the clearance of rotation and the movement clearance in X-Y plane of mounting in fixed scroll. The details of the compressor's performance in this study are measured that include energy efficiency ratio (E.E.R.), capacity, power consumption, volumetric efficiency, noise and amplitude of vibration. The measured results show that the backlash has major effect on E.E.R, the range of variation is 16.3%, and the movement clearance in X-Y plane influenced the noise significantly, the range of variation is 12.4%.

INTRODUCTION

The scroll-type compressor (STC) is known for its higher efficiency, lower noise, and smaller vibration. This paper will focus on the performance evaluation for the low side hermatic scroll compressor which key art is utilized a fixed scroll with axial compliant mechanism to achieve tip sealing under all operating conditions. In general, The optimum mechanism of axial compliance depends on the optimum mounting accuracy of the fixed scroll. Based on the balance of performance requirements and manufacturing effectivenesses, optimize the mounting accuracy of fixed scroll through manufacturing and assembling tolerances are very important for commercialization of the STC.

In this study, an experimental analysis has been carried out for the tolerance decision of fixed scroll assembly, special for the backlash, the clearance of rotation and the movement in X-Y plane which are the three critical factors that influence the performance of STC. After this investigation, we can feedback the optimum dimensions of related parts to designer and manufacturer.

Precise milling and grinding skill is utilized in this study to make sure the accuracy of related parts. Micrometer and thickness gauge are combined to check the assembling tolerance of mounting in the fixed scroll. Calorimeter with semi-anechonic chamber (the background noise is 40dBA), sound level meter and proximeter are used to measure the E.E.R., noise and vibration of the STC in this investigation, respectively.

EXPERIMENTAL DESCRIPTION

Figure 1 shows the simplified schematic of the scroll set with axial compliant mechanism of a hermatic STC. The key components on this mechanism include a fixed scroll and orbiting scroll, a set of locating members, a frame and a set of fasteners. The locating members are fastened with frame and have sliding connection faces to constrain the fixed scroll to slide up and down. The fixed scroll has a set of connection slots to match with the sliding connection faces of locating member. Moreover, the sliding connection faces of the locating member are also provided backlash on the top thereof with a retaining portion for preventing the fixed scroll from moving upward.

Figure 2(b) shows the ideal case of mounting in fixed scroll, it means that the fixed scroll will slide up only, but this is very difficult to achieve with manufacturing skill at present. For this reason, we modify the dimensions of the connection slots of fixed scroll and produce clearance between fixed scroll and the locating members that will cause the fixed scroll to rotate or move in X-Y plane independently. The total clearance of rotate and movement with fixed scroll are simulated by the reasonable manufacturing skill and our real assembly conditions. The detailed descriptions are shown in Figure 2.

In this experiment, the operating condition used to evaluate the performance of the STC model is given in Table 1 and the specification of the STC model is shown in Table 2.

EXPERIMENTAL RESULTS AND DISCUSSIONS

Under varying the assembling tolerance of fixed scroll, the performance of the STC had been measured in our calorimeter when the STC operated on stable behavior. Based on the balance between machining capability and cost, in this study, the minimum clearance is 0.04mm on the rotation or movement in X-Y plane of mounting in fixed scroll. Each of the experimental information is summarized as follows:

1.The influence of the backlash of mounting in fixed scroll

In this experiment, the backlash has been produced by fine machining the retaining portion of locating member. The increases of backlash are from 0.03mm to 0.06mm with step by 0.005mm where the clearance of rotation and the movement in X-Y plane are holding in 0.04mm. The detailed description about backlash is shown in Figure 2(a).

Figure 3 and Figure 4 depict the influences of performance with backlash variation. The experimental results are given as below:

(1) As backlash is over 0.055mm or under 0.03mm, the STC operate unstable and then shut down.
(2) The maximum of the E.E.R. is around backlash = 0.045mm where the capacity is 6,625kcal/h, the power consumption is 2,453W and the volumetric efficiency is 92.5%. The E.E.R. is 2.70kcal/h/W
(3) The capacity and volumetric efficiency decrease sharply as the backlash is under 0.04mm, in addition, the power consumption increase sharply.
(4) The discharge temperature of the STC is from 117.2℃ to 124.2℃ while the backlash decreases from 0.04mm to 0.03mm.
(5) As the backlash = 0.03mm, the capacity and volumetric efficiency decrease to 6,277kcal/h and 89% respectively, the power consumption increases to 2,777W. The E.E.R. is 2.26kcal/h/W and the drop of E.E.R is 16.3% corresponding to the maximum value in this experiment.
(6) As the backlash increases, the noise and vibration decrease continuously. The lowest value of noise is 61.7dBA when the backlash is 0.05mm, the highest value is 65dBA as backlash = 0.03mm and the percentage of increment is 5.3%, in addition, the amplitude of vibration is from 12.8 μm to 15 μm.
(7) It can be found that the optimum backlash of this STC model is 0.04mm~0.05mm. As the backlash is smaller than 0.04mm, the friction loss of the scroll set will increase.

2.The influence of the clearance of rotation in fixed scroll mounting:

Figure 2(c) depicts the detailed description of total clearance of rotation in fixed scroll mounting. In this study, the backlash is holding in 0.05mm, we modified the width dimension of the connection slots of fixed scroll only and produce the clearance for fixed scroll rotation, the increase of total clearance of rotation in fixed scroll are from 0.04mm to 0.08mm with step by 0.005mm.

From Figure 5 and Figure 6, we can see the variation of performance is very small on this item. The detailed descriptions are summarized as follow:

(1) As the clearance is between 0.04mm and 0.06mm, the variation of E.E.R., the capacity, the power consumption and volumetric efficiency are very small, the noise and vibration are also stable.
(2) The average of E.E.R., capacity, power consumption and volumetric efficiency are 2.65kcal/h/W, 6,542kcal/h, 2,468W and 91.6%, respectively.
(3) As the clearance is 0.07mm, noise increased rapidly, the data is from 60dBA to 62.3dBA, but the amplitude of vibration decreased from 9.3 μm to 8.5 μm.
(4) As the clearance is over 0.07mm, the STC presents unstable operation and then shut down.
(5) From this investigation, the optimum of total clearance of rotation in fixed scroll mounting is 0.04mm~0.06mm on this STC model.

3.The influence of the movement in X-Y plane of mounting in fixed scroll:

The minimum of the movement in X-Y plane of mounting in fixed scroll is also set to 0.04mm under this experiment. The detailed description about the movement in X-Y plane is depicted in Figure 2(d). Use the fine milling skill and modify the dimensions of width and top arc of the connection slots of fixed scroll, the increases of the total clearance of movement in fixed scroll assembly are set from 0.04mm to 0.08mm with step by

0.005mm, the backlash is holding in 0.05mm also.

On this item, the detailed experimental data are shown in Figure 7 and Figure 8. Their influences are summarized as below:

(1) The performance has little change while the total clearance of movement is between 0.04mm and 0.05mm, the E.E.R. = 2.63kcal/h/W, the capacity = 6,485kcal/h, the power consumption = 2,466W and the noise = 59.5dBA.
(2) As the clearance is larger than 0.05mm, the E.E.R. and capacity are slow down and the power consumption is slow up, in addition, the noise increases sharply and continuously.
(3) The volumetric efficiency is slow down continuously as the movement in X-Y plane increases. The data is from 90.8% to 90.4%.
(4) When the clearance is equal to 0.07mm, the noise = 66.9dBA. The increase of noise is 12.4% corresponding to the lowest value of noise on this experiment.
(5) The amplitude of vibration has presented fluctuation and the data are higher than the other two experiments of above mention almost, the amplitude of vibration is from 14.6 μ m to 16.5 μ m.
(6) As the clearance of movement is over 0.07mm, the STC operates unstable and then shut down.
(7) On the experiment, the optimum clearance of movement in X-Y plane is 0.04~0.05mm.

CONCLUSIONS

This study demonstrated a simplified experiment to evaluate the optimum of assembly tolerance in STC. The optimum tolerance of related parts in assembly and some important results in this study are summarized as below:

(1) The optimum backlash of the axial compliant mechanism for fixed scroll sliding up and down is 0.04~0.05mm, in the meanwhile, the clearance of rotation and movement in X-Y plane of mounting in fixed scroll are 0.04~0.06mm and 0.04~0.05mm respectively.
(2) After optimization, the range of E.E.R., capacity, power consumption and volumetric efficiency are 2.63~2.70 kcal/h/W, 6,485~6,625 kcal/h, 2,453~2,468 W and 90.8%~92.5%, respectively.
(3) As the backlash is small than 0.03mm, the power consumption increased with increasing of the friction loss of the scroll set, moreover, the capacity and volumetric efficiency of the STC decreased sharply.
(4) As the backlash is over 0.05mm and the clearance of rotation and the movement in X-Y plane are larger than 0.07mm, the STC operate unstable and then shut down.
(5) The backlash and the movement in X-Y plane of mounting in fixed scroll have major effect on E.E.R. and noise respectively, the variation range of influence are 16.3% and 12.4% individually.
(6) The relationship between noise and amplitude of vibration with varying tolerance of assembly in this experiment are randomly which need to go on study.

ACKNOWLEDGMENTS

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2. The authors would also like to sincere thanks for support of the prototypes of STC to carry out this experiment from our cooperative company, the RECHI Precision Co., Ltd., in Taiwan.

REFERENCE

1. U.S. Patent Number 5,527,166.
2. J. Lee, et al, 1996, "Investigation of Axial Compliance Mechanism in Scroll Compressor", Proc. Of International Compressor Engineering Conference at Purdue, pp459-464.

Table 1: Compressor operating conditions

Condensing Temp.	Evaporating Temp.	Subcooling Temp.	Superheating Temp.	Room Temp.
54.4℃	7.2°C	8.3°C	27.8°C	35°C

Table 2: Specification of the STC model

Refrigerant	R-22
Capacity (W)	6600
Displacement (cc/rev)	36.6
Motor speed (rpm)	3470
Input Power	220V/1ϕ
Lubricants	Mineral oil
Shell type	Low pressure

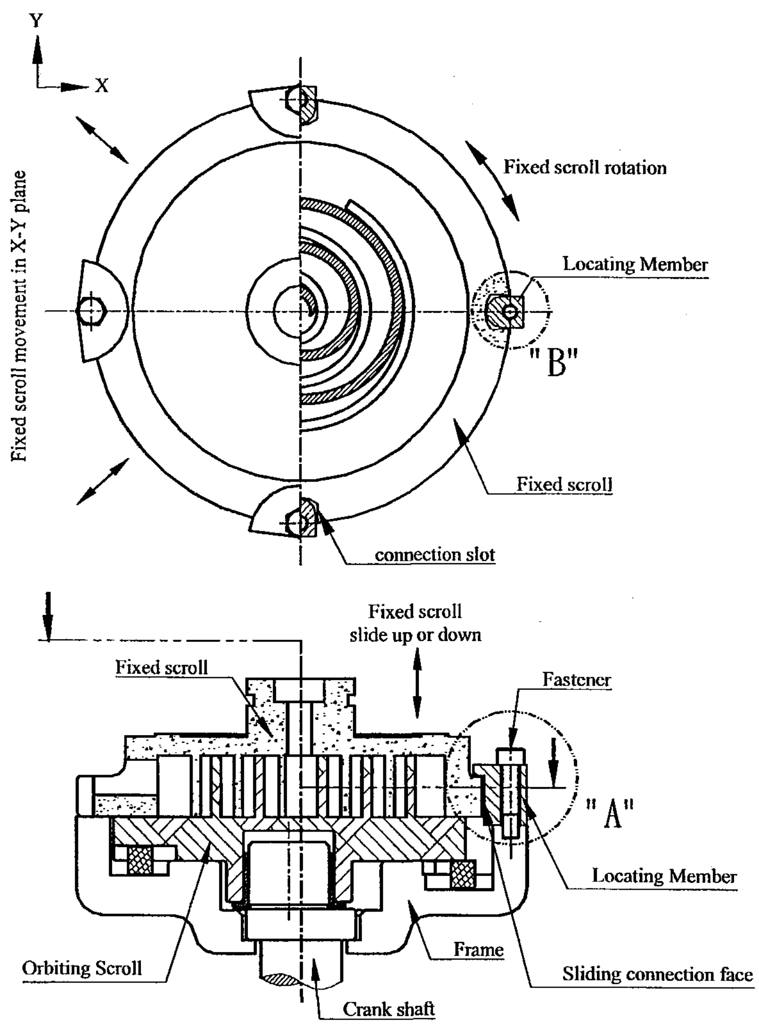
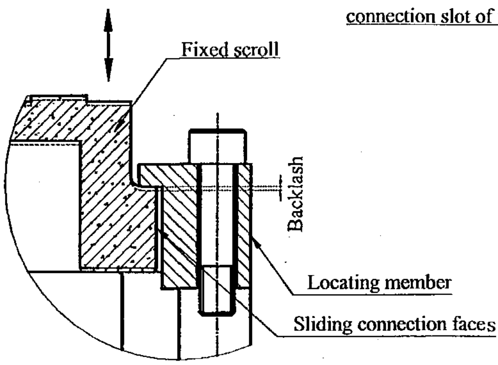
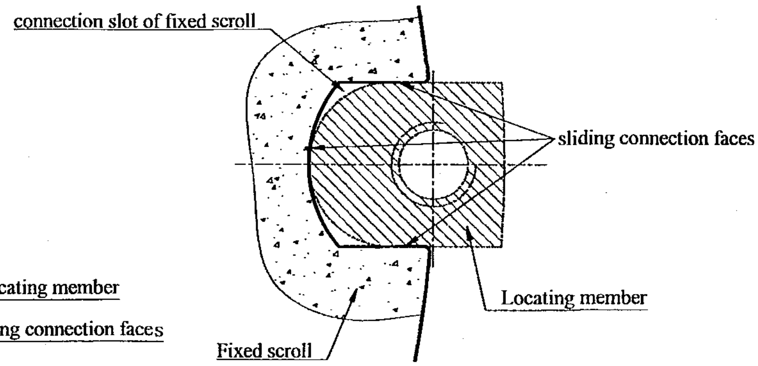


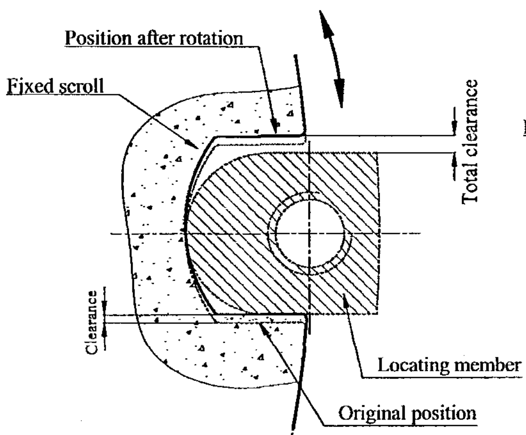
Figure 1 The simplified schematic of fixed scroll with axial compliant mechanism



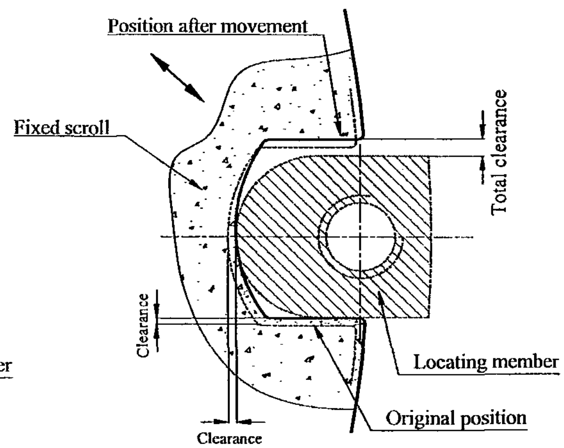
(a) Detail of section "A"
(Fixed scroll can slide up slightly)



(b) Detail of section "B"-Ideal case
(No clearance between Fixed scroll and locating member)



(c) Detail of section "B"-Case A
(Fixed scroll can rotate slightly)



(d) Detail of section "B"-Case B
(Fixed scroll can move slightly)

Figure 2 Detail description of section "A" and "B" in figure 1

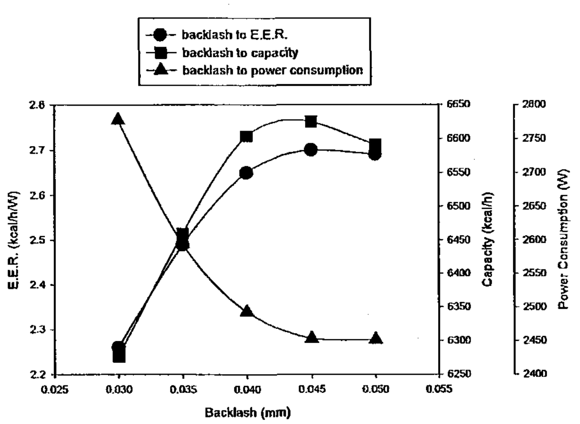


Figure 3 Performance variation with backlash of mounting in fixed scroll

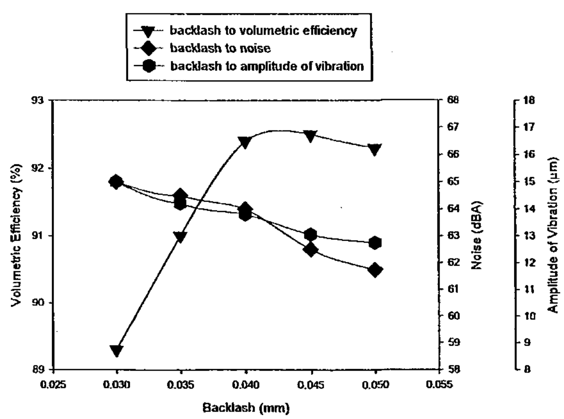


Figure 4 Influence of Noise and vibration with backlash of mounting in fixed scroll

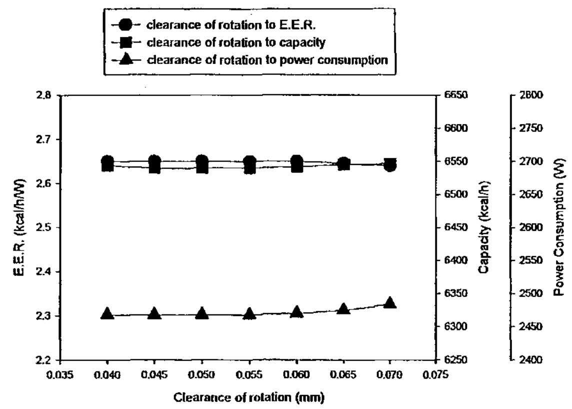


Figure 5 Performance variation with rotational clearance of mounting in fixed scroll

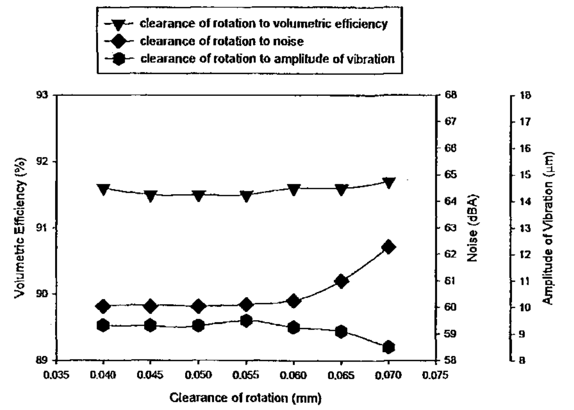


Figure 6 Influence of noise and vibration with rotational clearance of mounting in fixed scroll

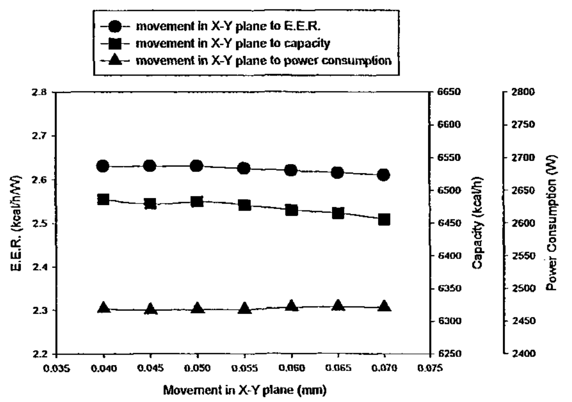


Figure 7 Performance variation with movement in X-Y plane of mounting in fixed scroll

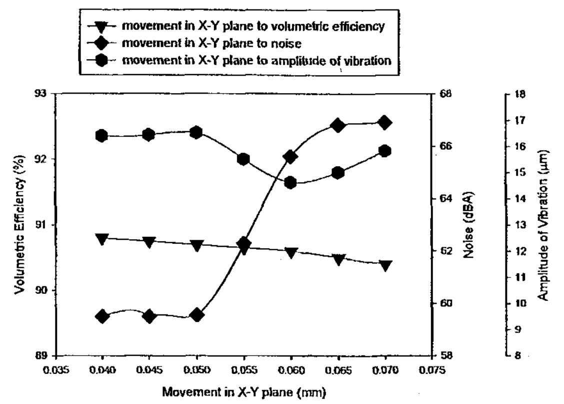


Figure 8 Influence of noise and vibration with movement in X-Y plane of mounting in fixed scroll